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FORM PTO-1390 (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 4223/PCT

US APPLICATION NO (If known, see 37 CFR 1.5): (unknown - to be assigned) 10/019336

INTERNATIONAL APPLICATION NO	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP00/05210	07. June 2000 (07.06.00)	18. June 1999 (18.06.99)

TITLE OF INVENTION Electromagnetic Actuator and Method for Adjusting Said Electromagnetic Actuator

APPLICANT(S) FOR DO/EO/US
Alexander VON GAISBERG; Dirk STRUBEL

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. [x] This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. [x] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [x] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [x] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [x] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [x] A translation of the International Application into English (35 U.S.C. 371(c)(2)) with Translator's Declaration.
7. [x] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [x] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [x] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [x] An Information Disclosure Statement under 37 CFR 1.97 and 1.98, Form PTO-1449, 4 reference(s).
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [x] A FIRST preliminary amendment. to minimize the filing fee.
    [x] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [x] Other items or information:
    a. a Return Receipt Postcard;
    b. Form PTO-2038 to cover the filing fee;
    c. 2 sheets of formal drawings with 3 Figs.;
    d. copy of International Search Report with English Version;
    e. marked-up version of Literal Trans. Pages 5, 7 and 9.

NOTE: The Priority of German Patent Application 199 27 823.7, filed in the Federal Republic of Germany on June 18, 1999 is claimed under 35 U.S.C. §119.

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
(not known - to be assigned) 10/019336	PCT/EP00/05210	4223/PCT

17. [x] The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO .... ~~$970.00~~		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .... $890.00 ~~$840.00~~		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... ~~$760.00~~		
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) .... ~~$670.00~~		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) .... ~~$96.00~~		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 0	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	7 - 20 =	0	X $18.00	$ 0	
Independent claims	2 - 3 =	0	X $78.00	$ 0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $260.00	$ 0	

TOTAL OF ABOVE CALCULATIONS =	$ 890.00	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).	$ 0	
SUBTOTAL =	$ 890.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$ 0	
TOTAL NATIONAL FEE =	$ 890.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +	$ 0	
TOTAL FEES ENCLOSED =	$ 890.00	
	Amount to be: refunded	$
	charged	$

a. [x] Form PTO-2038 (Credit Card Payment Form) ~~A check~~ in the amount of $ 890.00 to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. ________ in the amount of $________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [x] The Commissioner is hereby authorized to charge any deficiency in or additional fees which may be required, or credit any overpayment to Deposit Account No. 50-0507. ~~A duplicate copy of this sheet is enclosed.~~

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO

CUSTOMER NO.: 021553

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Walter F. Fasse
SIGNATURE

Walter F. Fasse 12/18/01
NAME

36132
REGISTRATION NUMBER

10/019336

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DOCKET NO.: 4223/PCT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN THE MATTER OF THE **PCT NATIONAL PHASE PATENT APPLICATION**

OF: Alexander VON GAISBERG et al. |

USSN: TO BE ASSIGNED - NEW |

FILED: December 18, 2001 |

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FOR: Electromagnetic Actuator and Method for Adjusting Said Electromagnetic Actuator

INTERNATIONAL SERIAL NO.: PCT/EP00/05210
INTERNATIONAL FILING DATE: 07. JUNE 2000 (07.06.00)

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ASSISTANT COMMISSIONER FOR PATENTS
BOX PCT
WASHINGTON, D. C. 20231

December 18, 2001

FIRST PRELIMINARY AMENDMENT TO MINIMIZE THE FILING FEE

Dear Sir:

In order to minimize the filing fee, please amend the above identified patent application as follows before calculating the filing fee.

Referring to the Literal Translation of International Application PCT/EP00/05210

In the Claims:

Please cancel claims **4, 5 and 6.**

Claims **1 to 3** and **7** are maintained for calculating the filing fee.

REMARKS:

After calculating the filing fee, please further enter the accompanying Second Preliminary Amendment which introduces new claims **8**, **9** and **10** for examination.

Respectfully submitted,

Alexander VON GAISBERG et al.
Applicant

By

Walter F. Fasse
Patent Attorney
Reg. No.: 36132
Tel. No.: (207) 862-4671
Fax. No.: (207) 862-4681
P. O. Box 726
Hampden, ME 04444-0726

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WFF:ar/4223/PCT
Encls.: postcard

10/019336

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DOCKET NO.: 4223/PCT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN THE MATTER OF THE **PCT NATIONAL PHASE PATENT APPLICATION**

OF: Alexander VON GAISBERG et al.

USSN: TO BE ASSIGNED - NEW

FILED: December 18, 2001

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ASSISTANT COMMISSIONER FOR PATENTS
BOX PCT
WASHINGTON, D. C. 20231

December 18, 2001

SECOND PRELIMINARY AMENDMENT

Dear Sir:

After calculating the filing fee, but before the first examination, please amend the above identified application as follows.

In the Specification: (Referring to the Literal Translation)

Please delete and replace the paragraph at **page 4, line 12 to page 5, line 13**, to read as follows:

According to the Fig. 1, the actuator according to the invention comprises a push rod or valve stem 4 that is in

force transmitting cooperation with a gas exchange valve 5, an armature 1 secured with the valve stem 4 perpendicularly to the valve stem longitudinal axis, an electromagnet 3 acting as a closing magnet, as well as a further electromagnet 2 acting as an opening magnet, which is arranged spaced apart from the closing magnet 3 in the direction of the valve stem longitudinal axis. The electromagnets 2, 3 respectively comprise an energizing or exciting coil 20 or 30, and pole surfaces lying across from one another. By means of an alternating energization of both electromagnets 2, 3, that is to say the exciting coils 20 or 30, the armature 1 is moved back and forth between the electromagnets 2, 3 along a stroke travel that is limited by the electromagnets 2, 3. A spring arrangement with a first spring 61 acting in the opening direction onto the armature 1 and a second spring 62 acting in the closing direction onto the armature 1 effectuates that the armature 1 is held in a neutral equilibrium position between the electromagnets 2, 3 in the de-energized condition of the exciting coils 20, 30. Furthermore, adjusting or setting means 71, 72 for setting the pre-stressing of the springs 61, 62 are provided. The setting means 71, 72 may, for example, be embodied as disks, which effectuate a compression of the springs 61, 62, and thereby prescribe the pre-stressing of the respective springs 61, 62. They may, however, also be controllably embodied, and enable a stepless variation of the pre-stressing.

Please delete and replace the paragraph at **page 6, line 14 to page 7, line 23**, to read as follows:

The stroke travel distance Im of the armature 1, over which the armature 1 travels - the motion of the armature 1 is referred to as flight in the following - is limited due to the prescribed spacing distance between the electromagnets 2, 3. The progressions of the spring forces of the two springs 61, 62, that is to say the forces with which the springs 61, 62 act on the armature 1, are dependent on the armature position I and can be described in connection with spring characteristic curves. In the force versus travel distance diagram of Fig. 2, the spring characteristic curve of the first spring 61 is referenced with F1, and the spring characteristic curve of the second spring 62 is referenced with F2. During the flight of the armature 1 from the upper end position to the lower end position, that is to say from the armature position 0 to the armature position Im, the force of the first spring 61 increases at first from a holding value F11 to a maximum value F13, which is achieved at the armature position Ix, in order to thereafter fall off to an end value F10 lying below the holding value F11, whereby the end value F10 is achieved at the armature position Im, that is to say in connection with the armature 1 lying against the opening magnet 2. In contrast, the spring force of the second spring 62 increases from an end value F20, which is effective in the in the upper end position of the armature 1, monotonously

but non-linearly to a holding value F21, which is achieved in the lower end position of the armature 1. The end values F10, F20 give the pre-stressing of the respective spring 61 or 62; they are adjusted or set in such a manner so that the area A1 under the spring characteristic curve F1 is equal to the area A2 under the spring characteristic curve F2. The areas A1 and A2 in that context correspond to the energy that is stored in the respective spring 61, 62, if these are compressed due to the motion of the armature. The two spring characteristic curves F1, F2 intersect each other at a point that prescribes the energetic center position Ie of the armature 1; this energetic center position Ie, which the armature 1 takes up with de-energized electromagnets 2, 3, generally does not correspond with the geometric center position between the electromagnets 2, 3 in connection with springs with different spring characteristic curves.

Please delete and replace the paragraph at **page 9, lines 8 to 20**, to read as follows:

The energy that is stored in the first spring 61 if the armature 1 is moved from its lower end position to its upper end position, is also measured in the same manner as described above, namely by measuring the progression of the spring force of the first spring 61 that results from the armature motion, and by integration of this progression over the spring travel distance, through which the first

spring 61 is thereby compressed. Next, the energy values that have been determined in this manner are compared with one another, and the pre-stressing of the first spring 61 is adjustingly set in such a manner so that the same energy is stored in the two springs 61, 62, if these are compressed by the stroke travel distance Im. The actuator is only installed into the internal combustion machine after this adjustment.

<u>In the Claims</u>:

Claims **1 to 3** and **7** are maintained unchanged.

Claims **4, 5 and 6** have previously been cancelled in applicants' First Preliminary Amendment.

Please enter new claims **8, 9** and **10** as follows.

8. (new) Electromagnetic actuator according to claim 1, characterized in that setting means (71, 72) for setting the pre-stressing of the springs (61, 62) are provided.

9. Electromagnetic actuator according to claim 8, characterized in that measuring means for measuring the progressions of the spring forces of the springs (61, 62) are provided.

10. Electromagnetic actuator according to claim 9, characterized in that control means for controlling the

setting means in accordance with the measured progressions of the spring forces are provided.

REMARKS:

1) Examination of the present U. S. National Phase Application is to proceed on the basis of claims 1 to 3 and 7 to 10. Claims 8, 9 and 10 are directly based on the translated PCT International Application claims 4, 5 and 6, except for omitting multiple dependencies.

2) A few typographical errors (e.g. in reference numbers) that existed in the PCT International Application text and the literal English translation thereof have been corrected in the present amendment of the specification. A marked-up version of the amended pages of the specification is enclosed to show the amendatory subject matter. No new matter has been introduced. Any further informalities of the literally translated specification and claims will be addressed after receiving the first Office Action.

3) It is noted that the International Preliminary Examination Report indicates that at least claims 5 to 7 (i.e. present claims 9, 10 and 7) satisfy all criteria for patentability under the PCT.

4) Favorable consideration and allowance of claims 1 to 3 and 7 to 10 are respectfully requested.

Respectfully submitted,

Alexander VON GAISBERG et al.
Applicant

By
Walter F. Fasse
Patent Attorney
Reg. No.: 36132
Tel. No.: (207) 862-4671
Fax. No.: (207) 862-4681
P. O. Box 726
Hampden, ME 04444-0726

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Docket #4223
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"Marked-up Version"

stroke travel that is limited by the electromagnets 2, 3. A spring arrangement with a first spring 61 acting in the opening direction onto the armature 1 and a second spring 62 acting in the closing direction onto the armature 1 effectuates that the armature 1 is held in a neutral equilibrium position between the electromagnets 2, 3 in the de-energized condition of the exciting coils 20, 30. Furthermore, adjusting or setting means 71, 72 for setting the pre-stressing of the springs 61, 62 are provided. The setting means 71, 72 may, for example, be embodied as disks, which effectuate a compression of the springs $\boxed{71, 72}$ 61, 62, and thereby prescribe the pre-stressing of the respective springs $\boxed{71, 72}$ 61, 62. They may, however, also be controllably embodied, and enable a stepless variation of the pre-stressing.

For starting the actuator, one of the electromagnets 2, 3 is energized, that is to say switched on, by applying an exciting voltage to the corresponding exciting coil 20 or 30, or a transient start-up oscillation routine is initiated, by means of which the armature 1 is first set into oscillation by alternating energization of the electromagnets 2, 3, in order to strike against the pole surface of the closing magnet 2 or the pole surface of the opening magnet 3 after a start-up oscillation transient time.

With a closed gas exchange valve 5, the armature 1 lies against the pole surface of the closing magnet 3 as shown in Fig. 1, and it is held in this position - the upper end position - as long as the closing magnet 3 is energized. In order to open the gas exchange valve 5, the closing magnet 3 is switched off, and next

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a maximum value F13, which is achieved at the armature position Ix, in order to thereafter fall off to an end value F10 lying below the holding value F11, whereby the end value F10 is achieved at the armature position Im, that is to say in connection with the armature 1 lying against the opening magnet 2. In contrast, the spring force of the second spring 62 increases from an end value F20, which is effective in the in the upper end position of the armature 1, monotonously but non-linearly to a holding value F21, which is achieved in the lower end position of the armature 1. The end values F10, F20 give the pre-stressing of the respective spring 61 or 62; they are adjusted or set in such a manner so that the area A1 under the spring characteristic curve F1 is equal to the area A2 under the spring characteristic curve F2. The areas A1 and A2 in that context correspond to the energy that is stored in the respective spring 61, 62, if these are compressed due to the motion of the armature. The two spring characteristic curves F1, F2 61, 62 intersect each other at a point that prescribes the energetic center position Ie of the armature 1; this energetic center position Ie, which the armature 1 takes up with de-energized electromagnets 2, 3, generally does not correspond with the geometric center position between the electromagnets 2, 3 in connection with springs with different spring characteristic curves.

On the one hand, the substantial advantage of the first spring 61, due to the maximum value F13 of its spring characteristic curve F1, is that it is in the position to store so much energy, that the armature 1 will be moved with high velocity during the de-stressing of the first spring 61, which leads to short switch-

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corresponding to the stroke travel distance Im of the armature 1, and the progression of the spring force, which results thereby, is measured section-wise and integrated section-wise over the spring travel distance. The result of this integration corresponds to the energy that is stored in this context in the second spring 62. Thereby, the measurement of the spring force can be carried out by means of a load cell or a measuring gage.

The energy that is stored in the first spring 61 if the armature 1 is moved from its lower end position to its upper end position, is also measured in the same manner as described above, namely by measuring the progression of the spring force of the first spring 61 that results from the armature motion, and by integration of this progression over the spring travel distance, through which the first spring 61 is thereby compressed. Next, the energy values that have been determined in this manner are compared with one another, and the pre-stressing of the first spring 61 is adjustingly set in such a manner so that the same energy is stored in the two springs 61, $\boxed{61}$ 62, if these are compressed by the stroke travel distance Im. The actuator is only installed into the internal combustion machine after this adjustment.

In the present example embodiment, the actuator is adjusted before placing it into operation. Also conceivable, however, are an adjustment during the operation, and an after-adjustment dependent on operating parameters. In this case, the adjusting or setting means are controllably embodied, and the progressions of the spring forces are measured with measuring means, onto which the springs act, for example with pressure sensors, espe-

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LITERAL TRANSLATION OF PCT INTERNATIONAL APPLICATION PCT/EP00/05210 FILED ON JUNE 7, 2000

Electromagnetic Actuator and Method for Adjusting Said Electromagnetic Actuator

The invention relates to an electromagnetic actuator according to the preamble of the patent claim 1 and a method for the adjusting of an electromagnetic actuator according to the preamble of the patent claim 6.

An electromagnetic actuator for operating a gas exchange valve in an internal combustion machine is known from the DE 196 31 909 A1. The actuator comprises two electromagnets arranged at a spacing distance relative to one another, and an armature that is in operative connection with the gas exchange valve and that is movable back and forth by magnetic force between the electromagnets against the force of two respectively counteracting springs. The actuator further comprises setting means, with which the position of the armature is set to the geometric center position between the two end positions of the armature in connection with de-energized electromagnets. In this regard, the high dependency of the energy requirement of the actuator on production tolerances is found to be disadvantageous.

Therefore, the invention is based on the object to provide an electromagnetic actuator according to the preamble of the patent claim 1, of which the energy requirement slightly depends on the production tolerances. The invention is further based on the object to provide a method according to the preamble of the

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patent claim 6, through which the dependency of the energy requirement of the actuator on production tolerances is minimized.

The object is achieved in an electromagnetic actuator according to the preamble of the patent claim 1 by the characterizing features of the patent claim 1, and in a method according to the preamble of the patent claim 7 by the characterizing features of the patent claim 7.

Advantageous embodiments and further developments are evident from the dependent claims.

According to the invention, the springs are pre-stressed in such a manner that the same energy will be stored in both springs in connection with a compression of the springs respectively by a spring travel distance prescribed by the limited stroke travel distance of the armature. Hereby one achieves, that the armature, when it is released from its two end positions and freely oscillates, will approach close to the two electromagnets to the same extent. As a result thereof, the influence of production-necessitated tolerances of the components, and especially of the springs, on the oscillating behavior of the armature is reduced. Moreover, the total energy requirement of the actuator is optimized, because both electromagnets comprise the same current requirement due to the armature approaching equally closely to the two electromagnets. Namely, if the armature would approach more closely to the one electromagnet than to the other during the free oscillation, then the current requirement of the one electromagnetic would drop by a certain amount, but the current

requirement of the other electromagnet would increase by a multiple of this amount, so that also the total energy requirement of the actuator would increase relative to the optimal value.

Preferably, at least one of the springs comprises a non-linear spring characteristic, advantageously a characteristic with a maximum value at a position of the armature lying between the electromagnets. Due to the non-linear spring characteristic of one or both of the springs, it is on the one hand ensured that the armature is accelerated with large forces, which has a high switching frequency as a result, and on the other hand one thereby achieves that small forces act in the end positions of the armature, so that also the energy requirement of the actuator for holding the armature in its end positions is small.

For the adjustment of this electromagnetic actuator, for each spring the course or progression of the spring force is measured, which spring force arises if the respective spring is compressed by a spring travel distance corresponding to the stroke travel distance of the armature. The energy, which is stored in the respective spring due to the compression thereof, is determined from the measured curves or progressions of the spring forces. Next, the pre-stressing of one or both springs is set in such a manner that the same energy is stored in both springs.

The adjustment of the actuator can be carried out during the manufacturing of the actuator, but an adjustment during the operation is also conceivable, in order to compensate changes of

operating values or parameters, as they may arise, for example, due to temperature effects, wear, or aging.

The invention will be described in greater detail below in connection with an example embodiment, with reference to the Figures, wherein:

Fig. 1 shows an electromagnetic actuator for operating a gas exchange valve in an internal combustion machine,

Fig. 2 shows a first force versus travel distance diagram with spring characteristic curves,

Fig. 3 shows a second force versus travel distance diagram with spring characteristic curves.

According to the Fig. 1, the actuator according to the invention comprises a push rod or valve stem 4 that is in force transmitting cooperation with a gas exchange valve 5, an armature 1 secured with the valve stem 4 perpendicularly to the valve stem longitudinal axis, an electromagnet 3 acting as a closing magnet as well as a further electromagnet 2 acting as an opening magnet, which is arranged spaced apart from the closing magnet 3 in the direction of the valve stem longitudinal axis. The electromagnets 2, 3 respectively comprise an energizing or exciting coil 20 or 30, and pole surfaces lying across from one another. By means of an alternating energization of both electromagnets 2, 3, that is to say the exciting coils 20 or 30, the armature 1 is moved back and forth between the electromagnets 2, 3 along a

stroke travel that is limited by the electromagnets 2, 3. A spring arrangement with a first spring 61 acting in the opening direction onto the armature 1 and a second spring 62 acting in the closing direction onto the armature 1 effectuate that the armature 1 is held in a neutral equilibrium position between the electromagnets 2, 3 in the de-energized condition of the exciting coils 20, 30. Furthermore, adjusting or setting means 71, 72 for setting the pre-stressing of the springs 61, 62 are provided. The setting means 71, 72 may, for example, be embodied as disks, which effectuate a compression of the springs 71, 72, and thereby prescribe the pre-stressing of the respective springs 71, 72. They may, however, also be controllably embodied, and enable a stepless variation of the pre-stressing.

For starting the actuator, one of the electromagnets 2, 3 is energized, that is to say switched on, by applying an exciting voltage to the corresponding exciting coil 20 or 30, or a transient start-up oscillation routine is initiated, by means of which the armature 1 is first set into oscillation by alternating energization of the electromagnets 2, 3, in order to strike against the pole surface of the closing magnet 2 or the pole surface of the opening magnet 3 after a start-up oscillation transient time.

With a closed gas exchange valve 5, the armature 1 lies against the pole surface of the closing magnet 3 as shown in Fig. 1, and it is held in this position - the upper end position - as long as the closing magnet 3 is energized. In order to open the gas exchange valve 5, the closing magnet 3 is switched off, and next

the opening magnet 2 is switched on. The first spring 61 acting in the opening direction accelerates the armature 1 through or beyond the rest position. By means of the opening magnet 2 which is now energized, additional kinetic energy is supplied to the armature 1, so that it reaches the pole surface of the opening magnet 2 despite possible friction losses, and there - at the bottom end position which is shown with dashed lines in Fig. 1 - is held until the switching off of the opening magnet 2. For the renewed closing of the gas exchange valve 5, the opening magnet 2 is switched off and the closing magnet 3 is next again switched on. The armature 1 is thereby moved by the second spring 62 to the closing magnet 3 and is held there on its pole surface.

The stroke travel distance Im of the armature 1, over which the armature 1 travels - the motion of the armature 1 is referred to as flight in the following - is limited due to the prescribed spacing distance between the electromagnets 2, 3. The progressions of the spring forces of the two springs 61, 62, that is to say the forces with which the springs 61, 62 act on the armature 1, are dependent on the armature position I and can be described in connection with spring characteristic curves. In the force versus travel distance diagram of Fig. 2, the spring characteristic curve of the first spring 61 is referenced with F1, and the spring characteristic curve of the second spring 62 is referenced with F2. During the flight of the armature 1 from the upper end position to the lower end position, that is to say from the armature position 0 to the armature position Im, the force of the first spring 61 increases at first from a holding value F11 to

a maximum value F13, which is achieved at the armature position Ix, in order to thereafter fall off to an end value F10 lying below the holding value F11, whereby the end value F10 is achieved at the armature position Im, that is to say in connection with the armature 1 lying against the opening magnet 2. In contrast, the spring force of the second spring 62 increases from an end value F20, which is effective in the in the upper end position of the armature 1, monotonously but non-linearly to a holding value F21, which is achieved in the lower end position of the armature 1. The end values F10, F20 give the pre-stressing of the respective spring 61 or 62; they are adjusted or set in such a manner so that the area A1 under the spring characteristic curve F1 is equal to the area A2 under the spring characteristic curve F2. The areas A1 and A2 in that context correspond to the energy that is stored in the respective spring 61, 62, if these are compressed due to the motion of the armature. The two spring characteristic curves 61, 62 intersect each other at a point that prescribes the energetic center position Ie of the armature 1; this energetic center position Ie, which the armature 1 takes up with de-energized electromagnets 2, 3, generally does not correspond with the geometric center position between the electromagnets 2, 3 in connection with springs with different spring characteristic curves.

On the one hand, the substantial advantage of the first spring 61, due to the maximum value F13 of its spring characteristic curve F1, is that it is in the position to store so much energy, that the armature 1 will be moved with high velocity during the de-stressing of the first spring 61, which leads to short switch-

ing times, despite the small holding value F11. Due to the small holding value F11, on the other hand, the current requirement for holding the armature 1 in its upper end position, and therewith the energy requirement of the actuator, is small.

In the force versus travel distance diagram according to Fig. 3, the spring characteristic curve F2 of the second spring 62, with an increasing spacing distance I between armature 1 and closing magnet 2, comprises at first a decreasing progression, then an increasing progression, and thereafter again a decreasing progression. The areas A1, A2 under the spring characteristic curves F1, F2 of the springs 61, 62 are once again equally large. For these spring characteristic curves F1, F2 it is shown to be advantageous, that the difference ΔF between the two spring characteristic curves F1, F2, that is to say the resulting force acting on the armature 1, is large for a large range of the spacing distance I between the armature 1 and closing magnet 3. As a result of that, the gas exchange valve 5 may also be opened against a combustion chamber internal pressure, that is to say the energy requirement of the opening magnet 2 is small due to the high resulting force ΔF that is effective during the opening process.

The adjustment of the actuator is carried out before the installation of the actuator in the internal combustion machine. Thereby, first the pre-stressing of the second spring 62 is adjustingly set to the end value F20, at which a secure or reliable closing of the gas exchange valve 5 is ensured. Next, the second spring 62 is compressed by the spring travel distance

corresponding to the stroke travel distance Im of the armature 1, and the progression of the spring force, which results thereby, is measured section-wise and integrated section-wise over the spring travel distance. The result of this integration corresponds to the energy that is stored in this context in the second spring 62. Thereby, the measurement of the spring force can be carried out by means of a load cell or a measuring gage.

The energy that is stored in the first spring 61 if the armature 1 is moved from its lower end position to its upper end position, is also measured in the same manner as described above, namely by measuring the progression of the spring force of the first spring 61 that results from the armature motion, and by integration of this progression over the spring travel distance, through which the first spring 61 is thereby compressed. Next, the energy values that have been determined in this manner are compared with one another, and the pre-stressing of the first spring 61 is adjustingly set in such a manner so that the same energy is stored in the two springs 61, 61, if these are compressed by the stroke travel distance Im. The actuator is only installed into the internal combustion machine after this adjustment.

In the present example embodiment, the actuator is adjusted before placing it into operation. Also conceivable, however, are an adjustment during the operation, and an after-adjustment dependent on operating parameters. In this case, the adjusting or setting means are controllably embodied, and the progressions of the spring forces are measured with measuring means, onto which the springs act, for example with pressure sensors, espe-

cially with piezocrystals. The adjusting or setting means are then controlled by control means, dependent on the measured spring forces, in such a manner so that the same energy is stored in both springs in connection with the maximum compression of the springs 61, 62 that is possible during the operation.

Patent Claims:

1. Electromagnetic actuator with two electromagnets arranged at a spacing distance relative to one another, and an armature (1) that is movable back and forth along a stroke travel distance (Im) between the electromagnets (2, 3) against the force of two springs (61, 62) acting against each other, characterized in that the springs (61, 62) are pre-stressed in such a manner, so that the same energy (A1, A2) is stored in both springs (61, 62) in connection with a compression of the springs (61, 62) that is prescribed by the stroke travel distance (Im) of the armature (1).

2. Electromagnetic actuator according to claim 1, characterized in that at least one of the springs (61, 62) comprises a non-linear spring characteristic curve (F1).

3. Electromagnetic actuator according to claim 2, characterized in that the spring characteristic curve (F1) of at least one of the springs (61, 62) comprises a maximum value (F13) at a position (Ix) of the armature (1) spaced away from the two electromagnets (2, 3).

4. Electromagnetic actuator according to one of the claims 1 to 3, characterized in that setting means (71, 72) for setting the pre-stressing of the springs (61, 62) are provided.

5. Electromagnetic actuator according to claim 4, characterized in that measuring means for measuring the progressions of the spring forces of the springs (61, 62) are provided.

6. Electromagnetic actuator according to claim 5, characterized in that control means for controlling the setting means in accordance with the measured progressions of the spring forces are provided.

7. Method for the adjusting of an electromagnetic actuator with two electromagnets (2, 3) arranged at a spacing distance relative to each other, and an armature (1) movable back and forth along a stroke travel distance between the electromagnets (2, 3) against the force of two springs (61, 62) acting against one another, characterized in that, for each spring (61, 62) the progression (F1, F2) of the spring force is measured, which results if the respective spring (61, 62) is compressed by a spring travel distance corresponding to the stroke travel distance (lm) of the armature (1), that in connection with the measured progressions (F1, F2) of the spring forces, the energy (A1, A2) is determined, which is stored in the respective spring (61, 62) due to the compression thereof, and that the pre-stressing (F10, F20) of one or both springs (61, 62) is set in such a manner so that the same energy (A1, A2) is stored in both springs (61, 62).

Docket #4223/PCT
INV.: Alexander VON GAISBERG et al
Title: Electromagnetic Actuator and Method For Adjusting Said Electromagnetic Actuator

10/019336

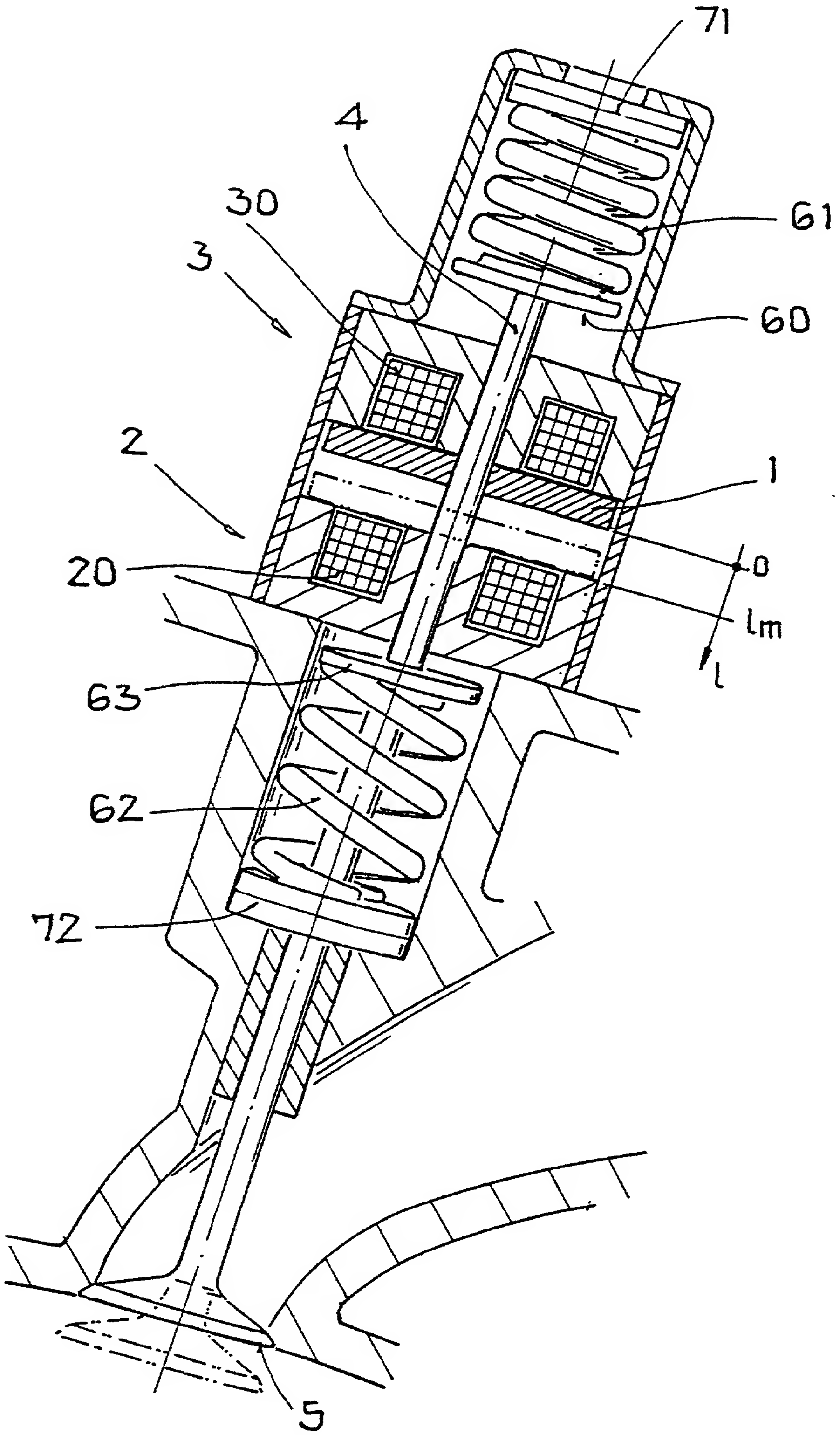

FIG. 1

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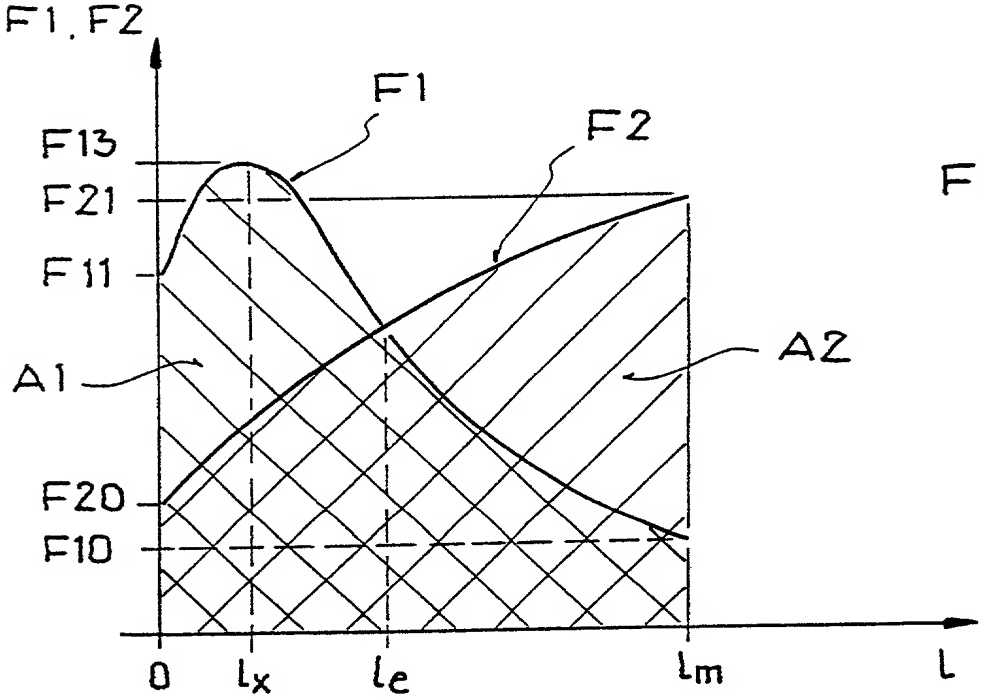

FIG. 2

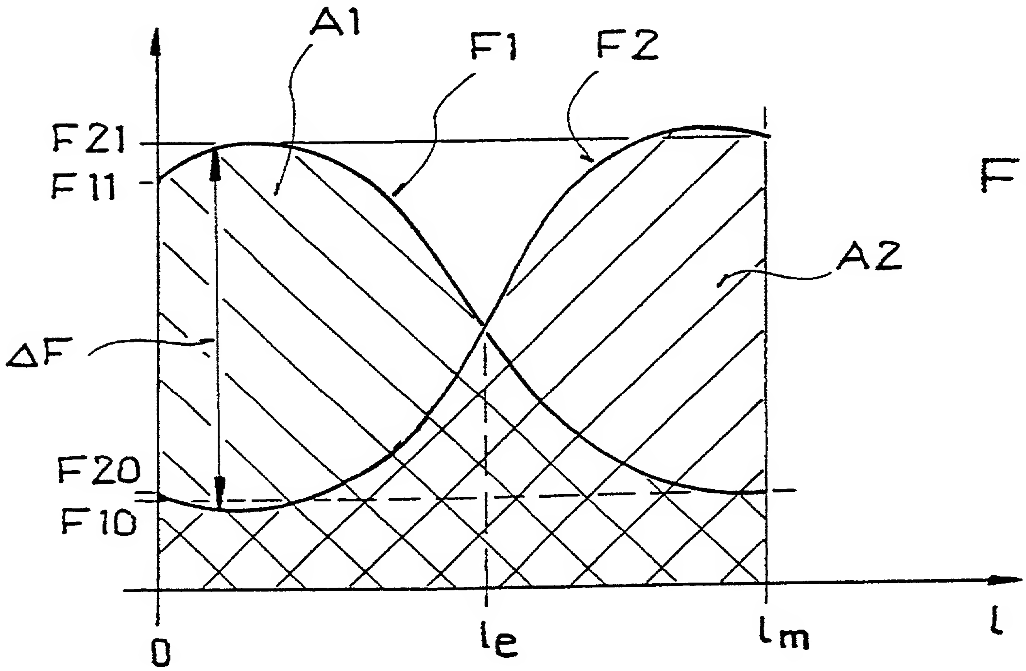

FIG. 3

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63) WITH POWER OF ATTORNEY

☐ Declaration Submitted with Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	4223
First Named Inventor	Alexander von GAISBERG
COMPLETE IF KNOWN	
Application Number	/
Filing Date	
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

ELECTROMAGNETIC ACTUATOR AND METHOD FOR ADJUSTING SAID ELECTROMAGNETIC ACTUATOR✓

(Title of the Invention)

the specification of which

☐ is attached hereto

OR

☒ was filed on (MM/DD/YYYY) 06/07/2000✓ as United States Application Number or PCT International Application Number PCT/EP00/05210✓ and was amended on (MM/DD/YYYY) ______ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
199 27 823.7 ✓	Fed. Rep. of Germany ✓	06/18/1999 ✓	☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	
		☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (*if applicable*)

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☒ Customer Number 021553 → *Place Customer Number Bar Code Label here*

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR : ☐ A petition has been filed for this unsigned inventor

1-00

Given Name (first and middle [if any])	Alexander	Family Name or Surname	VON GAISBERG		
Inventor's Signature	A. v. Gaisberg			Date	18.08.01
Residence: City	71717 Beilstein DEX	State		Country Fed. Rep. of Germany	Citizenship German
Mailing Address	c/o DaimlerChrysler AG Postfach 35 35				
Mailing Address					
City	Heilbronn	State		ZIP 74025	Country Fed. Rep. of Germany

NAME OF SECOND INVENTOR: ☐ A petition has been filed for this unsigned inventor

2-00

Given Name (first and middle [if any])	Dirk	Family Name or Surname	STRUBEL		
Inventor's Signature	Dirk Strubel			Date	15.08.01
Residence: City	70327 Stuttgart DEX	State		Country Fed. Rep. of Germany	Citizenship German
Mailing Address	c/o DaimlerChrysler AG Postfach 35 35				
Mailing Address					
City	Heilbronn	State		ZIP 74025	Country Fed. Rep. of Germany

☐ Additional inventors are being named on the ____ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto.

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